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## Center for Electronics and Electrical Engineering

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Covering Center Programs,
January to March 1989,
with 1989 CEEE Events Calendar

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National Institute of Standards and Technology
National Engineering Laboratory
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# INTRODUCTION TO JUNE 1989 ISSUE OF THE CEEE TECHNICAL PROGRESS BULLETIN

This is the twenty-sixth issue of a quarterly publication providing information on the technical work of the National Institute of Standards and Technology (formerly the National Bureau of Standards) Center for Electronics and Electrical Engineering. This issue of the CEEE Technical Progress Bulletin covers the first quarter of calendar year 1989.

Organization of Bulletin: This issue contains abstracts for all Center papers released for publication by NIST in the quarter and citations and abstracts for Center papers published in the quarter. Entries are arranged by technical topic as identified in the table of contents and alphabetically by first author under each subheading within each topic. Unpublished papers appear under the subheading "Released for Publication". Papers published in the quarter appear under the subheading "Recently Published". Following each abstract is the name and telephone number of the individual to contact for more information on the topic (usually the first author). This issue also includes a calendar of Center conferences and workshops planned for calendar year 1989 and and 1990 and a list of sponsors of the work.

Center for Electronics and Electrical Engineering: Center programs provide national reference standards, measurement methods, supporting theory and data, and traceability to national standards.

The metrological products of these programs aid economic growth by promoting equity and efficiency in the marketplace, by removing metrological barriers to improved productivity and innovation, by increasing U. S. competitiveness in international markets through facilitation of compliance with international agreements, and by providing technical bases for the development of voluntary standards for domestic and international trade. These metrological products also aid in the development of rational regulatory policy and promote efficient functioning of technical programs of the Government.

The work of the Center is divided into two major programs: the Semiconductor Technology Program, carried out by the Semiconductor Electronics Division in Gaithersburg, MD, and the Signals and Systems Metrology Program, carried out by the Electrosystems Division in Gaithersburg and the Electromagnetic Fields and Electromagnetic Technology Divisions in Boulder, CO. Key contacts in the Center are given on the back cover; readers are encouraged to contact any of these individuals for further information. To request a subscription or for more information on the Bulletin, write to CEEE Technical Progress Bulletin, National Institute of Standards and Technology, Metrology Building, Room B-358, Gaithersburg, MD 20899 or call (301) 975-2220.

Center sponsors: The Center Programs are sponsored by the National Institute of Standards and Technology and a number of other organizations, in both the Federal and private sectors; these are identified on page 23.

Note on Publication Lists: Guides to earlier as well as recent work are the publication lists covering the work of each division. These lists are revised and reissued on an approximately annual basis and are available from the originating division. The current set is identified in the Additional Information section, page 19.

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KEY CONTACTS IN CENTER, CENTER ORGANIZATION . . . . . back cover

## SEMICONDUCTOR TECHNOLOGY PROGRAM

### Dimensional Metrology

Recently Published

Nyyssonen, D., **A New Approach to Image Modeling and Edge Detection in the SEM**, Proceedings SPIE - Society of Photo-Optical Instrumentation Engineers (Box 10, Bellingham, WA 98227-0010), Vol. 921, Integrated Circuit Metrology, Inspection, and Process Control II, pp. 48-56 (1988).

The need for feature-size measurements on microchips for VLSI and other developing technologies with micrometer and submicrometer dimensions has resulted in using scanning electron microscopes (SEMs) for critical-dimension measurements during fabrication. However, good measurement practice requires the ability to accurately predict the observed signal output for any given feature. The model used to predict the output then becomes the basis for measurement algorithms, error analysis, and proper calibration techniques. The SEM, especially for secondary electron imaging and low-beam voltages, has heretofore lacked the ability to quantitatively predict image waveforms at the 0.01-$\mu$m level needed for submicrometer dimensional control. This paper describes such a model for SEM imaging and edge detection.
[Contact: Beverly M. Wright, (301) 975-2166]

Nyyssonen, D., **Narrow-Angle Laser Scanning Microscope System for Linewidth Measurements on Wafers**, NISTIR 88-3808 (April 1989).

The integrated-circuit industry in its push to finer and finer line geometries approaching submicrometer dimensions has created a need for ever-accurate and precise feature-size measurements to establish tighter control of fabrication processes. In conjunction with the NIST Semiconductor Linewidth Metrology Program, a unique narrow-angle laser measurement system was developed. This report describes the theory, optical design, and operation of this system and includes computer software useful for characterizing the pertinent optical parameters and images for patterned thin layers. For thick layers, the physics is more complex, and only elements of the theory are included here. However, for more detail the reader is referred to several related reports listed in the references.
[Contact: Beverly M. Wright, (301) 975-2166]

Postek, M.T., Larrabee, R.D., and Keery, W.J., **An Approach to Accurate X-Ray Mask Measurements in a Scanning Electron Microscope**, NISTIR 89-4047 (January 1989).

This paper presents the concept and some preliminary experimental data on a new method for measuring critical dimensions on masks used for x-ray lithography. The method uses a scanning electron microscope in a transmitted-scanning electron microscope imaging mode and can achieve nanometer precision. Use of this technique in conjunction with measurement algorithms derived from electron-beam interaction modeling may ultimately enable measurements of these masks to be made to nanometer accuracy.
[Contact: Beverly M. Wright, (301) 975-2166]

Postek, M.T., and Tiberio, R.C., **A Lithographic SEM Magnification Standard**, Research Accomplishments, 1987-1988, National Nanofabrication Facility at Cornell, unpaged (1988).

The National Institute of Standards and Technology is actively developing submicrometer standards for the scanning electron microscope. This report summarizes the design concepts for a new lithographic scanning electron microscope (SEM) magnification standard that covers a wide range of magnifications and that is usable over a wide range of electron-beam energies. The results of evaluating the first prototype are

Dimensional Metrology (cont'd.)

discussed, and the definition achieved in its 0.1-$\mu$m lines and spaces is illustrated.
[Contact: Beverly M. Wright, (301) 975-2166]

Photodetectors

Released for Publication

Geist, J., Stapelbroek, M. G., and Petroff, M. D., **The Absorption Cross Section of As in Si**, to be published in the Proceedings of SPIE - The International Society for Optical Engineering, P.O. Box 20, Bellingham, WA 98227.

Infrared absorption cross sections of As in Si near zero Kelvin have recently been measured in two different investigations. The average of the integrals of the cross section over photon wavenumber was $8.64 \times 10^{-13}$ $cm^{-1}$. This is nearly equal to the value predicted by the oscillator-strength sum rule. Between 500 and 1000 $cm^{-1}$, the absorption cross sections reported here agree very well with 0.7 times the currently accepted formula for the photoionization cross section of As in Si. Calibration errors in spreading resistance measurements on epitaxial layers seem to be the cause of the 0.7 multiplicative error in the photoionization formula. Above 1000 $cm^{-1}$, 0.7 times the value from the formula predicts a larger photoionization cross section than the absorption cross section reported here. This is apparently caused by the impact ionization of donor electrons from impurity atoms by energetic photoionized electrons.
[Contact: Jon Geist, (301) 975-2066]

Recently Published

Geist, J., **Blocked Impurity Band and Superlattice Detectors: Prospects for Radiometry**, Proceedings of the International Conference on Optical Radiometry, Inst. Phys. Conf. Ser. No. 92, NPL, Teddington, United Kingdom, April 12-13, 1988, pp. 99-110 (1989).

Blocked Impurity Band detectors and photomultipliers, which have been described by Petroff and Stapelbroek, may be suitable for use as high-accuracy standards for low-background optical radiation measurements extending from the near ultraviolet to beyond 25 $\mu$m in the infrared. The current status of their development from the point of view of standards applications is reviewed.

Superlattice technology offers new materials properties, new degrees of freedom, and new possibilities for optical radiation detectors displaying a large range of tailorability and tunability. GaAs/AlGaAs superlattices are used to illustrate new properties, HgTe/CdTe superlattices are used to illustrate new degrees of freedom, and GaAs-doping superlattices are used to illustrate tailorability and tunability.
[Contact: Jon Geist, (301) 975-2066]

Geist, J., **Infrared Absorption Cross Section of Arsenic in Silicon in the Impurity Band Region of Concentration** [original title began: **Study of Infrared ...**], Applied Optics, Vol. 28, No. 6, pp. 1193-1199 (15 March 1989).

The spectral dependence of the absorption cross section of As in Si near 0 K has been determined from infrared transmission measurements for three As concentrations (5.3, 8.4, and 15.9 x $10^{17}$ $cm^{-3}$) in the impurity band regime. The results demonstrate some features of physical interest. With increasing As concentration, the lines associated with the intra-atomic transitions broaden asymmetrically, while the integral of the total absorption cross section over photon energy is conserved as required by the oscillator-strength sum rule. It thus appears that the cross section for the intra-atomic transitions is conserved as the lines hybridize with the continuum. Comparison of our results with photoionization cross-section data suggests that the lines contribute to the cross section for

Photodetectors (cont'd.)

photoionization through field- and thermally assisted transitions when they are near the threshold for photoionization.
[Contact: Jon Geist, (301) 975-2066]

Geist, J., **Silicon Photodiode Self-Calibration**, Chapter 14, Theory and Practice of Radiation Thermometry, D. P. DeWitt and G. D. Nutter, Eds. (John Wiley & Sons, Inc., 1989), pp. 821-838.

This chapter presents the technique of silicon photodiode self-calibration which has demonstrated an accuracy that is superior to that of all other methods in the spectral region traditionally used for high-precision radiation thermometry. (The procedures necessary to achieve the highest accuracy self-calibration have now been described, and results of a comparison with a new, ultra-high accuracy, electrically calibrated, cryogenic cavity radiometer at 676 nm, which achieved agreement at the 0.02% level, have been reported.) The technique permits the determination of quantum efficiency and spectral reflectance of a high-quality shallow-junction silicon photodiode through a simple experimental procedure using relatively inexpensive equipment that is widely available.
[Contact: Jon Geist, (301) 975-2066]

Power Devices

Recently Published

Oettinger, F.F., **Thermal Resistance Measurements**, Tutorial Notes 1989, International Reliability Physics Symposium, Phoenix, Arizona, April 10, 1989, pp. 7.1 to 7.33.

PART I - POWER TRANSISTORS
The purpose of this tutorial is to review the thermal properties of power transistors and to discuss methods for characterizing these properties. The devices discussed include bipolar transistors and metal-oxide-semiconductor field-effect-transistors. Measurement problems common to these devices, such as deciding the reason a particular measurement is required, adequate reference temperature control, selection of a temperature-sensitive electrical parameter, and separation of electrical and thermal effects during measurement are addressed.

PART II - INTEGRATED CIRCUITS
The thermal characterization of the packaged integrated circuit chip surface/junction for the new generation of VLSI devices generally takes one of three forms: 1) indirect (i.e., electrical) measurements, 2) direct (e.g., infrared), measurements or 3) computer simulations of the surface/junction temperatures. Due to the inherent difficulties in measuring and analyzing the thermal properties of active integrated circuits, an approach using specifically designed thermal test chips for evaluation of new die attachment and packaging schemes is finding wide acceptance in the industry. In this tutorial, the three techniques for thermally characterizing integrated circuits are discussed in terms of their usefulness in characterizing VLSI ceramic packages.
[Contact: Frank F. Oettinger, (301) 975-2054]

Integrated Circuit Test Structures

Released for Publication

Suehle, J.S., and Galloway, K.F., **The Effects of Localized Hot-Carrier-Induced Charge in VLSI Switching Circuits**, to be published in the 17th Yugoslav Conference on Microelectronics, Nis, Yugoslavia, May 9-11, 1989.

This paper presents data collected from CMOS test circuits designed to characterize hot-carrier effects in digital switching circuits. Test circuits were configured as CMOS inverters, transmission gates, and NMOS transmission gates. The MOSFETs within the circuits could be

IC Test Structures (cont'd.)

probed so that the degradation of their dc characteristics could be directly measured. These circuits were hot-carrier-stressed under pulsed switching conditions similar to their operation in VLSI circuits. The results indicate that device degradation is strongly dependent on the circuit configuration and switching conditions. Transmission gate circuits exhibit a more severe degradation in switching characteristics than inverter circuits due to the localization of the hot-carrier-induced charge. The localized nature of hot-carrier-induced charge must be considered at the circuit simulation level to accurately assess the effect on circuit performance.
[Contact: John S. Suehle, (301) 975-2247]

Recently Published

Khera, D., Zaghloul, M.E., Linholm, L.W., and Wilson, C.L., **A Neural Network Approach for Classifying Test Structure Data**, Proceedings of ICMTS 1989, International Conference on Microelectronic Test Structures, Edinburgh, Scotland, March 13-14, 1989, pp. 201-204.

This paper describes a new approach for identifying and classifying semiconductor manufacturing process variations using test structure data. The technique described in this paper employs a machine-learning algorithm based on neural networks to train computers to detect patterns associated with test structure results. The objective of this work is to develop more reliable machine-learning classification procedures using test structure data from a semiconductor manufacturing environment. An example based on characterizing the performance of a 1-$\mu$m lithography process is presented as well as a description of the test chip.
[Contact: Dheeraj Khera, (301) 975-2240]

Schafft, H.A., **Test Methodology for Electromigration Characterization**, Tutorial Notes 1989, International Reliability Physics Symposium, Phoenix, Arizona, April 10, 1989, pp. 4.1 to 4.41.

This tutorial discusses in detail the test methodologies for characterizing the susceptibility of a metallization to electromigration failure under specified conditions in accelerated stress tests. The primary emphasis of the tutorial is the classical electromigration accelerated stress test in the context of three electromigration-related ASTM draft standards. Discussion includes many potential sources for measurement and analysis error and the rationale for significant details of the procedures in the draft standards.
[Contact: Harry A. Schafft, (301) 975-2234]

Schafft, H.A., Suehle, J.S., and Mirel, P.G.A., **Thermal Conductivity Measurements of Thin-Film Silicon Dioxide**, Proceedings of ICMTS 1989, International Conference on Microelectronic Test Structures, Edinburgh, Scotland, March 13-14, 1989, pp. 121-125.

Measurements of the thermal conductivity of micrometer-thick films of silicon dioxide are reported for the first time. Results show that the thermal conductivity is much lower than the values reported for bulk specimens, decreases with increasing temperature, and decreases with decreasing film thickness. This means that heating effects may be much larger than expected in accelerated stress tests and in other cases where joule heating can be a concern.
[Contact: Harry A. Schafft, (301) 975-2234]

Device Physics and Modeling

Released for Publication

Kim, J.S., **Determining the Channel Length of MOSFETs from the Fowler-**

Device Physics and Modeling (cont'd.)

**Nordheim Tunneling Current.**

A new method for determining the channel length of MOSFETs is proposed and experimentally tested. The method is based on the proportionality between the channel area and the body-to-gate current in the Fowler-Nordheim tunneling regime. The new method appears to be superior to two conventionally used techniques, namely, the channel-conductance and the gate-capacitance methods, since it circumvents measurement interferences due to the parasitics encountered in these methods.
[Contact: Jin S. Kim, (301) 975-2238]

Recently Published

Gaitan, M., and Mayergoyz, I., **A Numerical Analysis for the Small-Signal Response of the MOS Capacitor**, Solid-State Electronics, Vol. 32, No. 3, pp. 207-213 (1989).

The small-signal sinusoidal steady-state response of the MOS capacitor is simulated by solving the basic semiconductor equations using time perturbation analysis. The effect of nonuniform doping profiles, interface traps, and bulk traps is included. The model uses Fermi-Dirac statistics and Shockley-Read-Hall recombinations to describe the traps. This analysis is an improvement over previous analytical techniques since it stimulates the small-signal response of the MOS capacitor through its whole range of operation, including the frequency-dependent inversion layer response due to the traps.
[Contact: Michael Gaitan, (301) 975-2070]

Radiation Effects

Released for Publication

Suehle, J.S. and Galloway, K.F., **The Effects of Localized Hot-Carrier-Induced Charge in VLSI Switching Circuits**, to be published in the 17th Yugoslav Conference on Microelectronics, Nis, Yugoslavia, May 9-11, 1989.

This paper presents data collected from CMOS test circuits designed to characterize hot-carrier effects in digital switching circuits. Test circuits were configured as CMOS inverters, transmission gates, and NMOS transmission gates. The MOSFETs within the circuits could be probed so that the degradation of their dc characteristics could be directly measured. These circuits were hot-carrier stressed under pulsed switching conditions similar to their operation in VLSI circuits. The results indicate that device degradation is strongly dependent on the circuit configuration and switching conditions. Transmission gate circuits exhibit a more severe degradation in switching characteristics than inverter circuits due to the localization of the hot-carrier induced charge. The localized nature of hot-carrier induced charge must be considered at the circuit simulation level to accurately assess the effect on circuit performance.
[Contact: John S. Suehle, (301) 975-2247]

Insulators and Interfaces

Recently Published

Schafft, H.A., Suehle, J.S., and Mirel, P.G.A., **Thermal Conductivity Measurements of Thin-Film Silicon Dioxide**, Proceedings of ICMTS 1989, International Conference on Microelectronic Test Structures, Edinburgh, Scotland, March 13-14, 1989, pp. 121-125.

Measurements of the thermal conductivity of micrometer-thick films of silicon dioxide are reported for the first time. Results show that the thermal conductivity is much lower than the values reported for bulk specimens, decreases with increasing temperature, and decreases with decreasing film thickness. This means that heating effects may be much larger than expected in

Insulators and Interfaces (cont'd.)

accelerated stress tests and in other cases where joule heating can be a concern.
[Contact: Harry A. Schafft, (301) 975-2234]

Other Semiconductor Metrology Topics

Released for Publication

Littler, C.L., Zawadzki, W., Loloee, M.R., and Seiler, D.G., **Phonon-Assisted Donor-Shifted Magneto-Optical Resonances in N-InSb.**

We have observed and described new optical transitions between magneto-donor states in InSb, both with and without optic phonon assistance. The phonon-assisted transitions provide a unique opportunity to investigate high excited states of the magneto-Coulomb system, which imitates the hydrogen atom in gigantic magnetic fields. High-resolution data also reveal the presence of excited state magneto-donor transitions unknown until present.
[Contact: David G. Seiler, (301) 975-2074]

SIGNALS & SYSTEMS METROLOGY PROGRAM

FAST SIGNAL ACQUISITION, PROCESSING, AND TRANSMISSION

Waveform Metrology

Recently Published

Leedy, T. F., Lentner, K. J., Laug, O. B., and Bell, B. A., **Electrical Performance Tests for Hand-Held Digital Multimeters**, NISTIR 88-4021 (January 1989).

Electrical performance test procedures for battery-powered, hand-held digital multimeters were developed for the purpose of evaluating samples submitted by electronic instrument manufacturers in response to specifications issued by the U.S. Army Communications-Electronics Command. The detailed, step-by-step test procedures are based on the specifications by the Army and include sample data sheets and tables for the recording of interim data and final test results.

This report discusses the measurement principles and techniques underlying each of the procedures. In addition, the sources of measurement uncertainty are discussed.
[Contact: Thomas F. Leedy, (301) 975-2410]

Cryoelectronic Metrology

Released for Publication

Brasunas, J.C., Moseley, S.H., Lakew, B., Ono, R.H., McDonald, D.G., Beall, J.A., and Sauvageau, J., **Construction and Performance of a Thin-Film, Transition-Edge, High-Temperature-Superconductor Composite Bolometer.**

A composite, high-$T_c$ superconductor bolometer has been constructed, using a YBaCuO thin-film meander line 20 $\mu$m wide and 76,000 $\mu$m long as the thermometer. Radiation is absorbed by a thin film of bismuth deposited on a silicon substrate. The achieved dc bolometer response to a 500 K blackbody is 1900 V/W. If the observed 1/f noise can be reduced, the near-dc noise equivalent power is $4 \times 10^{-11}$ W/Hz$^{1/2}$. The response time is 32 s, dominated by the heat capacity of the $SrTiO_3$ substrate. Methods to reduce the time constant are discussed.
[Contact: Ronald H. Ono, (303) 497-3762]

Hamilton, C.A., McDonald, D.G., Sauvageau, J.E., and Whiteley, S., **Standards and High Speed Instrumentation.**

This paper reviews four applications of superconductivity which are of current interest in the field of metrology. These applications are Josephson series-array voltage standards, cryogenic

Cryoelectronic Metrology (cont'd.)

current comparators, a superconducting sampling oscilloscope, and a new bolometer based on a kinetic inductance thermometer.
[Contact: Clark A. Hamilton, (303) 497-3740]

Ono, R.H., and Beall, J.A., **Microlithography and Patterning of High-$T_c$ Thin Films**, to be published in the Proceedings of the 3rd International Sample Electronic Materials and Processes Conference, Los Angeles, California, June 19-23, 1989.

This paper reviews the techniques of microlithography which are used to pattern thin films of high-transition-temperature superconductors. We begin with a general discussion of the approaches which can be used: photoresist-based techniques such as etching and lift-off, ion implantation, and resistless patterning via laser ablation or ion-beam bombardment. A brief overview of high-$T_c$ device fabrication concludes the review.
[Contact: Ronald H. Ono, (303) 497-3762]

Recently Published

Cromar, M.W., Beall, J.A., Go, D., Masarie, K.A., Ono, R.H., and Simon, R.W., **Noise in DC SQUIDs with Nb/Al-Oxide/Nb Josephson Junctions**, IEEE Transactions on Magnetics, Vol. 25, No. 2, pp. 1005-1007 (March 1989).

We have developed a process which incorporates very high-quality Nb/Al-oxide/Nb Josephson junctions. The junctions have low subgap conductance yielding $V_m$ (quality factor defined as the product of the subgap resistance and the theoretical critical current as deduced from the normal-state resistance) greater than 50 mV for critical current densities of 1000 A/cm$^2$. Low-inductance superconducting quantum interference devices (SQUIDs) made with these junctions were apparently free from junction conductance fluctuations, at least for frequencies above 1 Hz. The SQUIDs exhibited flux noise of currently unknown origin.
[Contact: Michael W. Cromar, (303) 497-5375]

Hu, Q., Mears, C.A., Richards, P.L., and Lloyd, F.L., **MM Wave Quasioptical SIS Mixers**, IEEE Transactions on Magnetics, Vol. 25, No. 2, pp. 1380-1383 (March 1989).

We have tested the performance of planar superconductor-insulator-superconductor (SIS) mixers with log-periodic antennas at millimeter and submillimeter wave frequencies from 90 to 360 GHz. The large $\omega R_N C$ product ($\simeq$10 at 90 GHz) of our $Nb/NbO_x/Pb$-In-Au junctions requires an integrated inductive tuning element to resonate the junction capacitance at the operating frequencies. We have used two types of integrated tuning elements, which were designed with the aid of measurements using Fourier transform spectroscopy. Preliminary results indicate that the tuning elements can give very good mixer performance up to at least 200 GHz. An inductive wire in parallel with a five-junction array, gives a minimum mixer noise temperature of 115 K (double-side-band [DSB]) at 90 GHz with a full-width-at-half-maximum (FWHM) bandwidth of 8 GHz. An open-ended microstrip stub, in parallel with a single junction, gives minimum mixer noise temperatures of 150 and 200 K (DSB) near 90 and 180 GHz with FWHM bandwidths of 4 and 3 GHz, respectively. The relatively high mixer noise temperatures compared to those of waveguide SIS mixers in a similar frequency range are attributed mainly to the losses in our optical system, which is being improved.
[Contact: Frances L. Lloyd, (303) 497-3254]

Kautz, R.L., and Monaco, R., **Chaos and Catastrophe Near the Plasma Frequency in the RF-Biased Josephson Junction**, IEEE Transactions on Magnetics, Vol. 25, No. 2, pp. 1399-1403 (March 1989).

Cryoelectronic Metrology (cont'd.)

At bias frequencies much higher than the plasma frequency, the zero-voltage state of the rf-biased Josephson junction is known to span a range of dc bias proportional to the zero-order Bessel function of the rf amplitude. This pattern is modified at frequencies near the plasma frequency by the onset of chaotic instabilities and by the presence of cusp catastrophes.
[Contact: Richard L. Kautz, (303) 497-3391]

Ono, R.H., Beall, J.A., Cromar, M.W., Mankiewich, P.M., Howard, R.E., and Skocpol, W., **Switching Noise in $YBa_2Cu_3O_x$ Macrobridges**, IEEE Transactions on Magnetics, Vol. 25, No. 2, pp. 976-979 (March 1989).

We have observed intermittent switching in the voltage-current characteristics of $YBa_2Cu_3O_x$ micro-constrictions. This indicates that at a given bias point, there are multiple metastable voltage states with lifetimes which depend on the bias current and applied magnetic field. The microbridges are made of thin (<500-nm), polycrystalline films of $YBa_2Cu_3O_x$ which are patterned by liftoff into structures with dimensions ranging from less than 1 $\mu$m to 100 $\mu$m. Details of the fabrication process and the measurements are presented. The results are discussed in the context of fluctuations in the effective resistance of the bridge due to motion of trapped flux.
[Contact: Ronald H. Ono, (303) 497-3762]

Sauvageau, J.E., and McDonald, D.G., **Superconducting Kinetic Inductance Bolometer**, IEEE Transactions on Magnetics, Vol. 25, No. 2, pp. 1331-1334 (March 1989).

We are developing a bolometer with a temperature sensor based on the temperature dependence of the inductance of a superconducting microstrip line. As a first step in exploring this idea experimentally, we have designed experiments to test only the temperature sensor. The experimental devices are all-niobium inductance thermometers fabricated on silicon substrates which have been deeply etched to provided areas of relative thermal isolation. The ground plane superconductor is thin enough that its kinetic inductance dominates the audio-frequency impedance of the stripline near its critical temperature, i.e., at 0.9 $T_c$. This differential thermometer uses a commercial superconducting quantum interference device as the preamplifier. Results from the first experiments with these devices are given.
[Contact: Joseph E. Sauvageau, (303) 497-3988]

Laser Metrology

Recently Published

Scott, T.R., **NIST Optical Power Measurements**, Proceedings of the 1989 Measurement Science Conference, Anaheim, California, January 26-27, 1989, pp. 3C-19 to 3C-29.

The measurement of optical power (that is, laser power or energy at wavelengths and power levels of interest to the fiber optic community) at NIST is based upon a standard reference calorimeter called the C-series calorimeter. The C-series calorimeter is a national reference standard for measuring absolute energy and power levels of continuous-wave laser sources over a wide range of wavelengths. Various infrared laser sources and a calibrated beamsplitter measurement system are used to compare an electrically calibrated pyroelectric radiometer (ECRP) to the C-series calorimeter. The calibrated ECRP is then used as a laboratory standard. The calibration of measurement of optical power at NIST is reviewed starting with a discussion of the primary reference standard and the associated measurement system. The system used for calibrating optical power detectors is then discussed and

Laser Metrology (cont'd.)

the associated uncertainties are identified.
[Contact: Thomas R. Scott, (303) 497-3651]

Pulse Power Metrology

Released for Publication

Olthoff, J.K., and Hebner, R.E., **Assessment of Space Power Related Measurement Requirements of the Strategic Defense Initiative**, to be published as an NIST Technical Note.

A survey has been performed to determine the measurement requirements of space power related parameters for anticipated Strategic Defense Initiative (SDI) systems. These requirements have been compared to present state-of-the-art metrology capabilities as represented by the calibration capabilities of the National Institute of Standards and Technology. Metrology areas where present state-of-the-art capabilities are inadequate to meet SDI requirements are discussed, and areas of metrology-related research which appear promising to meet these needs are examined. Particular attention is paid to the difficulties of long-term, unattended sensor calibrations and long-term measurement reliability.
[Contact: James K. Olthoff, (301) 975-2431]

Olthoff, J.K., and Hebner, R.E., **Metrology Requirements of Future Space Power Systems**, to be published in Space Nuclear Power Systems 1989, M.S. El-Genk and M.D. Hoover, Eds., Orbit Book Co., Malabar, Florida.

Anticipated measurement requirements of future space power systems have been researched in a program initiated at the U.S. National Institute of Standards and Technology. These requirements have been compared with existing state-of-the-art measurement capabilities, and areas where present capabilities are inadequate have been discussed in this paper. Particular attention has been paid to the difficulties of determining measurement reliabilities for long-term, unattended sensor operation.
[Contact: James K. Olthoff, (301) 975-2431]

Optical Fiber Metrology

Released for Publication

Franzen, D.L., **Optical Fiber Measurements: Results of Interlaboratory Evaluations**, to be published in the Proceedings of SPIE Conference Digest, Boston, Massachusetts, September 6-9, 1988.

Results of industry-wide round-robin comparisons administered by the National Institute of Science and Technology (formerly National Bureau of Standards) and the Electronic Industries Association are presented. Multimode fiber parameters include attenuation, bandwidth, core diameter, and numerical aperture. Single-mode fiber parameters include cut-off wavelength and mode-field diameter.
[Contact: Douglas L. Franzen, (303) 497-3346]

Recently Published

Franzen, D.L., **Optical Fiber Metrology at the National Bureau of Standards** (now National Institute of Standards and Technology), Proceedings of the DOD/ANSI/EIA Fiber Optics Standardization Symposium, Arlington, Virginia, December 7-10, 1987, pp. 222-223.

The National Institute of Standards and Technology (NIST, formerly the National Bureau of Standards) has worked several years with the Electronic Industries Association (EIA) to evaluate fiber optic test procedures (FOTPs) drafted by the committee on Fibers and Materials, FO-6.6. Most parameters of multimode graded index fiber have been tested including attenuation, bandwidth, and core diameter. FOTPs that have been

Optical Fiber Metrology (cont'd.)

evaluated for single-mode fiber include cut-off wavelength and mode-field diameter. Three single-mode fibers have been characterized by NIST for spectral attenuation, cut-off wavelength and mode-field diameter.
[Contact: Douglas L. Franzen, (303) 497-3346/5342]

Li, X., and Gallawa, R.L., **Potential Errors in the Use of Optical Fiber Power Meters**, Proceedings of the SPIE - The International Society for Optical Engineering, Vol. 841, Fiber Optic Networks and Coherent Technology in Fiber Optic Systems II, pp. 231-233 (1987).

We discuss the potential for errors associated with the measurement of optical power in a field environment. Errors can arise because field use is often inconsistent with the calibration method. Errors may be due to the use of connectors of different types and due to variation amongst vendors for a given connector type. We consider two of the most popular connector types and discuss their effect on power measurements.
[Contact: Robert L. Gallawa, (303) 497-3761]

Oates, C.W., and Young, M., **Profile Inhomogeneity in Multimode-Graded Index Fibers**, Journal of Lightwave Technology, Vol. 7, No. 3, pp. 530-532 (March 1989).

We have measured the profile parameter of multimode-graded index fibers and found that it may vary azimuthally by 0.15 or more.
[Contact: Matt Young, (303) 497-3223/5342]

Scott, T.R., **NIST Optical Power Measurements**, Proceedings of the 1989 Measurement Science Conference, Anaheim, California, January 26-27, 1989, pp. 3C-19 to 3C-29.

The measurement of optical power (that is, laser power or energy at wavelengths and power levels of interest to the fiber optic community) at NIST is based upon a standard reference calorimeter called the C-series calorimeter. The C-series calorimeter is a national reference standard for measuring absolute energy and power levels of continuous-wave laser sources over a wide range of wavelengths. Various infrared laser sources and a calibrated beamsplitter measurement system are used to compare an electrically calibrated pyroelectric radiometer (ECRP) to the C-series calorimeter. The calibrated ECRP is then used as a laboratory standard. The calibration of measurement of optical power at NIST is reviewed starting with a discussion of the primary reference standard and the associated measurement system. The system used for calibrating optical power detectors is then discussed and the associated uncertainties are identified.
[Contact: Thomas R. Scott, (303) 497-3651]

Electro-Optic Metrology

Released for Publication

Hickernell, R.K., Aust, J.A., and Larson, D.R., **Optical Waveguide Attenuation Measured by Photothermal Displacement**, to be published in the Conference Digest of the Sixth International Topical Meeting on Photoacoustic and Photothermal Phenomena, Baltimore, Maryland, July 31-August 3, 1989.

We apply the photothermal displacement technique to the study of propagation loss in optical channel waveguides. Thermal expansion of the substrate surface due to the absorption of guided light is probed with a laser beam reflected from the surface. The technique is noncontact, has a high spatial resolution, and is applicable to a wide variety of waveguides, including packaged devices. We measure attenuation in ion-exchanged glass waveguides

Electro-Optic Metrology (cont'd.)

at a wavelength of 1.3 μm.
[Contact: Robert K. Hickernell, (303) 497-3455]

Recently Published

Bell, B.A., Perrey, A.G., and Sadler, R.A., **Gallium Arsenide (GaAs)-Based Photoconductive Switches for Pulse Generation and Sampling Applications in the Nanosecond Regime**, IEEE Transactions on Instrumentation and Measurement, Vol. 38, No. 1, pp. 92-97 (February 1989).

This paper describes the design of a set of optoelectronic switches having an interdigitated electrode structure and implemented with high-resistivity GaAs photoconductive substrates. A theoretical analysis is developed for determining the pulsed light ON state resistance (peak conductance), OFF state (dark) resistance, and the associated capacitances for the various designed gap geometries. Data are provided on the processing steps used in successfully fabricating a working set of switches based on the theoretical design. A test apparatus is used to make measurements of the pulsed light conductance of these devices having nominal gap spacings of 5, 10, 20, and 40 μm.
[Contact: Barry A. Bell, (301) 975-2402]

Other Fast Signal Topics

Released for Publication

Bennett, H.E., Guenther, A.H., Milam, D., and Newnam, B.E., **Laser Induced Damage in Optical Materials: 1987**, to be published as an NIST Special Publication.

The Nineteenth Annual Symposium on Optical Materials for High-Power Lasers (Boulder Damage Symposium) was held at the National Institute of Standards and Technology in Boulder, Colorado, October 26-28, 1987. The Symposium was held under the auspices of ASTM Committee F-1, Subcommittee on Laser Standards, with the joint sponsorship of NIST, the Defense Advanced Research Project Agency, the Department of Energy, the Office of Naval Research, and the Air Force Office of Scientific Research. Over 190 scientists attended the Symposium, including representatives of the United Kingdom, France, Japan, India, Canada, and the Federal Republic of Germany. The Symposium was divided into sessions concerning Materials and Measurements, Mirrors and Surfaces, Thin Films, and Fundamental Mechanisms. As in previous years, the emphasis of the papers presented at the Symposium was directed toward new frontiers and new developments. Particular emphasis was given to materials for high-power systems. The wavelength range of prime interest was from 10.6 μm to the uv region. Highlights included surface characterization, thin film substrate boundaries, and advances in fundamental laser-matter threshold interactions and mechanisms. The scaling of damage thresholds with pulse duration, focal area, and wavelength was discussed in detail. Harold E. Bennett of the Naval Weapons Center, Arthur H. Guenther of the Air Force Weapons Laboratory, David Milam of the Lawrence Livermore National Laboratory, and Brian E. Newnam of the Los Alamos National Laboratory were co-chairmen of the Symposium.
[Contact: Aaron A. Sanders, (303) 497-5341]

Recently Published

Cavcey, K.H., **Transmission Loss Through 6061 T-6 Aluminum Using a Pulsed Eddy Current Source**, Materials Evaluation, Vol. 47, pp. 216-216 (February 1989) [American Society for Nondestructive Testing, 4153 Arlingate Plaza, Columbus, Ohio 43228-0518].

One method of nondestructive testing in conductors is that of pulsed eddy currents (PECs). In this method, defects modify the electromagnetic field passing through the conductor, with

Other Fast Signal Topics (cont'd.)

respect to phase (delay) and attenuation. The conductor itself as a transmission medium also modifies the incident field from the PEC source with respect to phase and attenuation. It is therefore important to determine the intrinsic response and transmission loss for any medium of interest. This paper outlines a study of the frequency and phase response (with time-domain techniques based on the PEC source) for seven different thicknesses of aircraft-grade 6061 T-6 aluminum alloy.
[Contact: Kenneth H. Cavcey, (303) 497-3995]

Oates, C.W., and Young, M., **Microscope Objectives, Cover Slips, and Spherical Aberration**, Applied Optics, Vol. 26, No. 11, p. 2043 (June 1, 1987).

This short paper discusses the spherical aberration encountered when some microscope objectives are used without cover slips for purposes other than as components of a microscope. Most common objectives are designed for use with a cover slip that is 170 $\mu$m thick and has a refractive index of 1.522. When they are used without a cover slip, their image quality is apt to suffer as a result of spherical aberration. For a low enough numerical aperture, spherical aberration will not be a factor, and a low N.A. objective may be used with or without a cover slip. We wanted to know the highest N.A. for which the spherical aberration of the cover slip is not a factor.
[Contact: Matt Young, (303) 497-3223]

ELECTRICAL SYSTEMS

Power Systems Metrology

Released for Publication

Martzloff, F.D., and Leedy, T.F., **A Glimpse at Long-Term Effects of Momentary Overvoltages on Zinc Oxide Varistors**, to be published in the Proceedings of the Second International Varistor Conference, Schenectady, New York, December 4-5, 1988.

Because the prime function of varistors is diversion of high-energy surges, most of the attention is directed toward selecting the appropriate device rating to ensure long life under surge conditions. Some attention is also given to matching steady-state rating of the device to the power system voltage. However, during abnormal (and not well-defined) power system conditions, the line voltage can reach values that will cause substantial current in the varistor. Until the effects of these momentary overvoltages are better identified and understood, there will be a risk of near-term failure at worst and accelerated aging at best.
[Contact: Francois D. Martzloff, (301) 975-2409]

Misakian, M., **Measurements of Power Frequency Magnetic Fields.**

National Institute of Standards and Technology contribution to document in preparation by AC Fields Working Group, Power Engineering Society, Institute of Electronics and Electrical Engineers. The text of the final document is scheduled to be available from IEEE later this year.
[Contact: Martin Misikian, (301) 975-2426]

Misikian, M., Anderson, W.E., and Laug, O., **Drift Tubes for Characterizing Atmospheric Ion Mobility Spectra**, to be published in the Proceedings of the Sixth International Symposium on High Voltage Engineering, New Orleans, Louisiana, August 28-September 1, 1989.

Two drift tubes constructed of insulating cylinders with conductive guard rings on the inside walls were examined to determine their suitability for measuring ion mobility spectra at atmospheric pressure. One drift tube is of the pulse time-of-flight (TOF) type with adjustable drift distance, and the other is an ac-TOF drift tube similar in

Power Systems Metrology (cont'd.)

principle to a device reported by Van de Graaff. The latter tube was evaluated using sinusoidal and alternating-polarity pulse-voltage waveforms for gating the shutters.
[Contact: Martin Misikian, (301) 975-2426]

Van Brunt, R.J., and Kulkarni, S.V., **Method for Measuring the Stochastic Properties of Corona and Partial Discharge Pulses.**

A new method is described for measuring the stochastic behavior of corona and partial-discharge pulses which utilizes a pulse selection and sorting circuit in conjunction with a computer-controlled multichannel analyzer to directly measure various conditional and unconditional pulse-height and pulse-time-separation distributions. From these measured distributions, it is possible to determine the degree of correlation between successive discharge pulses. Examples are given of results obtained from measurements on negative, point-to-plane (Trichel-type) corona pulses in an $N_2/O_2$ gas mixture which clearly demonstrate that the phenomenon is inherently stochastic in the sense that development of a discharge pulse is significantly affected by the amplitude of, and time separation from, the preceding pulse. It is found, for example, that corona discharge pulse amplitude and time separation from an earlier pulse are not independent random variables. Discussions are given about the limitations of the method, sources of error, and data analysis procedures required to determine self-consistency of the various measured distributions.
[Contact: Richard J. Van Brunt, (301) 975-2425]

Recently Published

Hebner, R.E., **Measurement of Electrical Breakdown in Liquids**, Proceedings of the NATO Advanced Study Institute on the Liquid State and Its Electrical Properties, Sintra, Portugal, July 5-17, 1987 (Plenum Publishing Corp, New York, 1988), pp. 519-537.

The continuing development of light sources, high-speed cameras, and high-speed electronic measuring systems have made it possible to study the breakdown process in increasing detail. The four measurements described are high-speed photography of the breakdown process, measurement of the voltage and current, optical spectroscopy, and the measurement of acoustic emission. After a battery of measurement techniques has been developed, understanding of the breakdown process is gained by changing the system in known ways and determining the effect of these changes on the measured results. Parameters which have been investigated include types of liquids, chemical additives, particle density, pressure, viscosity, and the rate of rise of the applied voltage. These investigations have led to the identification of four modes of growth when the streamer initiates at a cathode and three modes when it initiates at an anode.
[Contact: William E. Anderson, (301) 975-2423]

Ramboz, J.D., **High-Current Measurement Techniques, Part II, 100-kA Source Characteristics and Preliminary Shunt and Rogowski Coil Evaluations**, NISTIR 89-4040 (March 1989).

The characterization of a 100-kA current source is discussed. This source is intended for use in the calibration of high-current sensors such as shunts and Rogowski coils commonly employed in resistance welders. The output current from the source is derived from SCR-gated signals in the form of bursts of "chopped" 60-Hz sinusoidal waveforms. These waveforms and their spectral content were investigated. The near-field magnetic field strength was mapped. Initial calibrations were performed on a 30-kA, 10-$\mu\Omega$ shunt. Preliminary results indicate a temperature coefficient of about 130 ppm/°C

Power Systems Metrology (cont'd.)

which is thought to be related to a thermally induced strain. Several Rogowski-coil-type current sensors were evaluated and calibrated. Each of the coils measured had outputs which were sensitive to the rotational position about the current-carrying conductor. The calibration philosophy and approach is discussed and estimates of measurement uncertainty are given. Suggested improvements for the measurement process are offered. Planned efforts are outlined.
[Contact: John D. Ramboz, (301) 975-2434]

Superconductors

Released for Publication

Ekin, J.W., Goodrich, L.F., Bray, S.L., Bergren, N.F., and Goldfarb, R.B., **Electromechanical Properties of Superconductors for DoE High-Energy Physics Applications**, to be published as an NIST Internal Report.

This report presents data on superconductor performance under mechanical load, which are needed for setting mechanical design constraints and measuring the electromechanical performance of NbTi superconductors for DoE high-energy physics magnet applications. Highlights of this report include the following: (1) The first measurements of the effect of axial tensile stress, applied at room temperature, on the critical current of NbTi superconductor strands have been made. The data show that the effect on the critical current is independent of the temperature at which the stress is applied; this result allows the existing 4-kbyte database to be used to determine critical current degradation from room-temperature fabrication stress, cool-down stress, and stress at 4 K generated when the magnet is energized. (2) In a study of cabled NbTi superconductors, the critical current variations along strands extracted from a Rutherford cable were measured. The results show that the principal mechanical degradation is extremely localized at the regions where the NbTi strand is bent around the edge of the cable. The degree of degradation depends on the orientation of the applied magnetic field. All conductors tested showed small resistive voltages at low current associated with current transfer in the regions of deformation. A systematic study of the effects of bending strain on the critical current of NbTi conductors has been performed.

The degradation of the critical current from bending strain is much greater at low electric field criteria $E_c$ than at high, suggesting that irregularity of the filament cross-sectional area introduced by bending may be the source of the $I_c$ degradation. By testing a series of similarly fabricated NbTi wires, it was found that the bend tolerance of a NbTi conductor can be enhanced by increasing the local copper-to-superconductor area ratio (LAR) and by using a filament diffusion barrier material made of vanadium, instead of Nb or Nb/CuNi. The dependence of the bend degradation on LAR represents a mechanical limit to reduction of the LAR when controlling filament-sausaging effects.

(3) Many high-energy-physics accelerators use high-permeability steel for the return flux path of the superconducting magnets. Measurements of the permeability, saturation magnetization, and intrinsic coercivity ($H_c$) of several high-permeability steel alloys were made. Values of $H_c$ at 76 K ranged from 110 A/m (1.4 Oe) for cold-rolled samples to 170 A/m (2.1 Oe) for hot-rolled plate. The results were independent of whether the field was parallel or perpendicular to the rolling direction. $H_c$ was slightly smaller at room temperature. At liquid-helium temperature, $H_c$ is expected to be slightly higher. The overall differences between cold-rolled steel samples were not

Superconductors (cont'd.)

significant with regard to saturation magnetization and intrinsic coercivity. [Contact: Jack W. Ekin, (303) 497-5448]

Goodrich, L.F., Bray, S.L., and Stauffer, T.C., **Thermal Contraction of Fiberglass-Epoxy Sample Mandrels and Its Effect on Critical-Current Measurements**, to be published in the Proceedings of the Sixth Japan-U.S. Workshop on High Field Superconductors, Boulder, Colorado, February 22-24, 1989.

A systematic study of the effect of sample-mounting techniques on the superconducting critical-current measurement was made in conjunction with the VAMAS (Versailles Agreement on Advanced Materials and Standards) interlaboratory comparison measurements. A seemingly small change in mandrel geometry can result in a 40% change in the measured critical current of a $Nb_3Sn$ sample at 12 T. This is a result of a change in the conductor pre-strain at 4 K caused by variation in thermal contraction between thick- and thin-walled fiberglass-epoxy composite (G-10) tubes. An approximate measure of the variations in thermal contraction (from room to liquid nitrogen temperature) indicates a 0.2% greater contraction for the thick-walled tube. This difference, combined with strain sensitivity measurements, is consistent with the observed decrease in critical current. Previous publications on the thermal contraction of G-10 have addressed the plate geometry, but not the tube geometry. The contraction of a G-10 plate is highly anisotropic. The radial contraction of a tube is different from the contraction of a plate, however, because the circumferential fiberglass is put into hoop compression by the epoxy, and the resulting contraction is a competition between the two structural components. This appears to be the source of the variation in thermal contraction with tube wall thickness.
[Contact: Loren F. Goodrich, (303) 497-3143]

Harman, G.G., **Comments on a Paper by Richardson and De Jonghe.**

This is a response to an earlier paper on aluminum cladding of silver-contacted YBaCuO superconductor ceramics. The authors envisioned using their method for production when such superconductors become practical. The response points out, with 8 references, the long history of reliability problems with the Ag-Al metallurgical couple, indicating that the proposed system cannot be improved without basic metallurgical changes.
[Contact: George G. Harman, (301) 975-2097]

Recently Published

Bray, S.L., and Ekin, J.W., **Effect of Room Temperature Stress on the Critical Current of NbTi**, Journal of Applied Physics, Vol. 65, No. 2, pp. 684-687 (15 January 1989).

Superconducting composites which are used in the construction of large-scale magnets may be subjected to several sources of mechanical stress. These stresses occur within three different temperature regimes: room temperature, the transition between room and liquid-helium temperatures, and at liquid-helium temperature (≈4 K). Until now, only critical-current degradation from stresses introduced at liquid-helium temperature have been measured. This paper presents the results of the first measurements of the effect on critical current of tensile stress applied at room temperature. The results indicate a simple general relationship, namely, that the stress effect on critical current of NbTi is independent of the temperature at which the stress is applied. This result may be of considerable benefit to the magnet designers since the existing data base of helium-temperature stress effects in NbTi is directly applicable to tensile stresses introduced at room temperature during magnet fabrication. The results should be particularly useful in setting stress limits in large magnet applica-

Superconductors (cont'd.)

tions where the combined fabrication and Lorentz forces are great.
[Contact: Steven L. Bray, (303) 497-5631]

Bray, S.L., Goodrich, L.F., and Dube, W.P., **Battery Powered Current Supply for Superconductor Measurements**, Review of Scientific Instruments, Vol. 60, No. 2, pp. 261-264 (February 1989).

In order to measure the critical current of superconductors, a high output current supply is required. In addition to high current capability, the supply should be designed to reduce ground loop problems, respond linearly to an input control signal, and minimize output noise. A current supply having these qualifications has been constructed and tested. Although the supply was originally designed for testing conventional superconductors, it has been successfully used in measurements on the high-critical-temperature ceramic superconductors as well. The supply can produce 1000-A output current with a noise level of approximately 0.05 A peak-to-peak. In addition to its normal operation as a controllable dc current source, two other specialized modes of operation have been developed and tested. In one mode, the supply is used as a source of dc-biased ac currents for testing the effect of dc-power-supply ripple on critical-current measurements. In the other mode, the supply is used in conjunction with a larger and noisier current source to form a hybrid supply. In the hybrid system, the smaller supply is used to increase the current output while greatly reducing the noise output of the larger supply. The specifics of all designs, modes of operation, and performance results are given.
[Contact: Loren F. Goodrich, (303) 497-3143]

Goldfarb, R.B., Ried, D.L., Kreilick, T.S., and Gregory, E., **Magnetic Evaluation of Cu-Mn Matrix Material for Fine-Filament Nb-Ti Superconductors**, IEEE Transactions on Magnetics, Vol. 25, No. 2, pp. 1953-1955 (March 1989).

Copper-manganese alloys have been proposed as matrix material for the reduction of coupling losses in fine-filament Nb-Ti superconductor wires. Magnetization and susceptibility measurements show that adverse magnetic effects arising from the spin-glass properties of this matrix are minimal for concentrations of Mn up to at least 4 percent.
[Contact: Ronald B. Goldfarb, (303) 497-3650]

Goodrich, L.F., and Bray, S.L., **Current Capacity Degradation in Superconducting Cable Strands**, IEEE Transactions on Magnetics, Vol. 25, No. 2, pp. 1949-1952 (March 1989).

The electromagnetic properties of NbTi strands extracted from Rutherford-type cables were studied to clarify the effect of mechanical deformation, caused by the cabling process, on the current capacity of the strands. Three different cables were studied, all of which are prototypes for the Superconducting Super Collider's dipole magnets. The extended cable strands were instrumented to allow measurement of the voltage across several key regions of mechanical deformation as a function of current and the orientation of the applied magnetic field. The resulting data are presented in terms of the strands' voltage profile as well as its critical current to more thoroughly characterize the conductors' electromagnetic properties. The cable strands show very localized reductions in current capacity that are well correlated with the regions of high mechanical deformation. For example, at a particular field orientation, the voltage across a portion of the strand that is only 3% of the total strand length contributes 92% of the total strand voltage. Two applied magnetic field orientations, parallel and perpendicular to the cable's width, are shown to have pronounced effects on the

Superconductors (cont'd.)

electrical properties of the strand. Both of these magnetic field orientations will arise in application.
[Contact: Loren F. Goodrich, (303) 497-3143]

Goodrich, L.F., Bray, S.L., and Stauffer, T.C., **$Nb_3Sn$ Critical Current Measurements on Tubular Fiberglass-Epoxy Mandrels**, IEEE Transactions on Magnetics, Vol. 25, No. 2, pp. 2375-2378 (March 1989).

A systematic study of the effect of sample mounting techniques on the superconducting critical-current measurement was made in conjunction with the VAMAS (Versailles Agreement on Advanced Materials and Standards) round-robin measurements. A seemingly small change in mandrel geometry can result in a 40% change in the measured critical current of a $Nb_3Sn$ sample at 12 T. This is a result of a change in the conductor pre-strain (at 4 K) due to variation in thermal contraction between thick- and thin-walled fiberglass-epoxy composite (G-10) tubes. An approximate measure of the thermal contraction (from room to liquid nitrogen temperature) variations indicate a 0.2% greater contraction for the thick-wall tube. This difference combined with strain sensitivity measurements is consistent with the observed decrease in critical current. Previous publications on the thermal contraction of G-10 have addressed the plate geometry but not the tube geometry. The contraction of a G-10 plate is highly anisotropic. However, the radial contraction of a tube is different than the contraction of a plate because the circumferential fiberglass is put in hoop compression by the epoxy and the resulting contraction is a competition between the two structural components. This appears to be the source of the thermal contraction variation with tube wall thickness.
[Contact: Loren F. Goodrich, (303) 497-3143]

Moreland, J., and Goodrich, L.F., **Ag Screen Contacts to Sintered $YBa_2Cu_3O_x$ Powder for Rapid Superconductor Characterization**, IEEE Transactions on Magnetics, Vol. 25, No. 2, pp. 2056-2059 (March 1989).

We have developed a new method for making current contacts and voltage taps to $YBa_2Cu_3O_x$ sintered pellets for rapid superconductor characterization. Ag wire screens are interleaved between calcined powder sections and then fired at 930°C to form a composite pellet for resistivity and critical current measurements. The Ag diffuses into the powder during the sintering process forming a proximity contact that is permeable to $O_2$. Contact surface resistivities (area-resistance product) range from 1 to 10 $\mu\Omega$-cm$^2$ at 77 K for the Ag-powder interface. In this configuration, current can be uniformly injected into the ends of the pellet through the bonded Ag screen electrodes. Also, Ag screen voltage contacts, which span a cross section of the pellet, may provide an ideal geometry for detecting voltage drops along the pellet, minimizing current transfer effects.
[Contact: John Moreland, (303) 497-3641]

Tachikawa, K., Itoh, K., Wada, H., Gould, D., Jones, H., Walters, C.R., Goodrich, L.F., Ekin, J.W., and Bray, S.L., **VAMAS Intercomparison of Critical Current Measurement in $Nb_3Sn$ Wires**, IEEE Transactions on Magnetics, Vol. 25, No. 2, pp. 2368-2374 (March 1989).

The VAMAS (Versailles Agreement on Advanced Materials and Standards) technical working party in the area of superconducting and cryogenic structural materials has recently carried out the first world-wide intercomparison of critical current, $I_c$, measurement on multifilamentary $Nb_3Sn$ wires. Three sample wires each were supplied by the European Community, Japan, and USA. The total number of participant labs was 25 (European Community 12, Japan 8, and USA 5). There were few restrictions for the

Superconductors (cont'd.)

$I_c$ measurement at participant labs. The standard deviations of the $I_c$ values reported from these labs varied from 6 to 20% at 12 tesla. Possible reasons of the $I_c$ deviation among labs are discussed.
[Contact: Loren F. Goodrich, (303) 497-3143]

Other Electrical Systems Topics

Released for Publication

Olthoff, J.K., and Hebner, R.E., **Assessment of Space Power Related Measurement Requirements of the Strategic Defense Initiative**, to be published as an NIST Technical Note.

A survey has been performed to determine the measurement requirements of space power related parameters for anticipated Strategic Defense Initiative (SDI) systems. These requirements have been compared to present state-of-the-art metrology capabilities as represented by the calibration capabilities of the National Institute of Standards and Technology. Metrology areas where present state-of-the-art capabilities are inadequate to meet SDI requirements are discussed, and areas of metrology-related research which appear promising to meet these needs are examined. Particular attention is paid to the difficulties of long-term, unattended sensor calibrations and long-term measurement reliability.
[Contact: James K. Olthoff, (301) 975-2431]

Olthoff, J.K., and Hebner, R.E., **Metrology Requirements of Future Space Power Systems**, to be published in Space Nuclear Power Systems 1989, M.S. El-Genk and M.D. Hoover, Eds., Orbit Book Co., Malabar, Florida.

Anticipated measurement requirements of future space power systems have been researched in a program initiated at the U.S. National Institute of Standards and Technology. These requirements have been compared with existing state-of-the-art measurement capabilities, and areas where present capabilities are inadequate have been discussed in this paper. Particular attention has been paid to the difficulties of determining measurement reliabilities for long-term, unattended sensor operation.
[Contact: James K. Olthoff, (301) 975-2431]

ELECTROMAGNETIC INTERFERENCE

Conducted Electromagnetic Interference

Recently Published

Martzloff, F.D., and Leedy, T.F., **Selecting Varistor Clamping Voltage: Lower is Not Better**, Proceedings of the 8th Electromagnetic Compatibility (EMC) Symposium, Zurich, Switzerland, March 7-9, 1989, pp. 137-142.

Surge protective devices, such as varistors, are applied to protect sensitive load equipment against power-line surges. The need to provide low clamping voltage, for protection of equipment with low inherent immunity, must be balanced against the risk of premature aging of the protective device, accelerating its aging. The paper describes four possible causes of such premature aging, calling for a more careful and thus more reliable application of protective devices.
[Contact: Francois D. Martzloff, (301) 975-2409]

ADDITIONAL INFORMATION

Fundamental Electrical Measurements

Released for Publication

Cage, M.E., **Semiclassical Scattering Corrections to the Quantum Hall Effect Conductivity and Resistivity Tensors.**

Ando, Matsumoto, and Uemura published an important paper in 1975 that greatly influenced the early experimental work

Additional Information (cont'd.)

on the quantum Hall effect. That paper showed in both a semiclassical scattering model and in a self-consistent Born approximation that there is a correction to the quantum Hall conductivity component $\sigma_{xy}$ of the conductivity tensor that is directly proportional to the diagonal conductivity component $\sigma_{xx}$. We provide a detailed derivation of their results using the semiclassical scattering (relaxation-time approximation) model. We then present the surprising result that, in the semiclassical scattering model, there is no correction to the quantum Hall resistivity tensor component $\rho_{xy}$ due to a finite value of $\rho_{xx}$.
[Contact: Marvin E. Cage, (301) 975-4248]

Lists of Publications

Reidy, A.M., and Gibson, K.A., **A Bibliography of the NIST Electromagnetic Fields Division Publications**, NISTIR 88-3900 (September 1988).

This bibliography lists publications by the staff of the National Institute of Standards and Technology's Electromagnetic Fields Division for the period from January 1970 through August 1988. Selected earlier publications from the Division's predecessor organizations are included.
[Contact: Kathryn A. Gibson, (303) 497-3132]

DeWeese, M.E., **Metrology for Electromagnetic Technology: A Bibliography of NBS Publications**, NBSIR 88-3097 (August 1988).

This bibliography lists the publications of the personnel of the Electromagnetic Technology Division of NIST in the period from January 1970 through publication of this report. A few earlier references that are directly related to the present work of the Division are included.
[Contact: Sarabeth Moynihan, (303) 497-3678]

Palla, J.C., and Meiselman, B., **Electrical and Electronic Metrology: A Bibliography of NBS Electrosystems Division Publications, NBS List of Publications 94** (January 1989).

This bibliography covers publications of the Electrosystems Division, Center for Electronics and Electrical Engineering, NIST, and of its predecessor sections for the period January 1968 to December 1988. A brief description of the Division's technical program is given in the introduction.
[Contact: Jenny C. Palla, (301) 975-2220]

Walters, E.J., **Semiconductor Measurement Technology, NBS List of Publications 72** [a bibliography of NBS publications concerning semiconductor measurement technology for the years 1962-1988] (March 1989).

This bibliography contains reports of work performed at the National Institute of Standards and Technology in the field of Semiconductor Measurement Technology in the period from 1962 through December 1988. An index by topic area and a list of authors are provided.
[Contact: E. Jane Walters, (301) 975-2050]

NEW CALIBRATION SERVICES OFFERED

The explosive growth of optical fiber use in the communications industry has resulted in a demand for calibration services. NIST's Boulder, Colorado, laboratory now offers **measurements of optical laser power and energy at wavelengths and power levels of interest to fiber optic producers and users.** Measurements are based on a standard reference instrument called the C-series calorimeter. An electrically calibrated pyroelectric radiometer (ECPR) is calibrated against the calorimeter and is then used to calibrate optical power meters at wavelengths of 850, 1300, and

Additional Information (cont'd.)

1550 nm. To improve calibration capabilities, NIST is preparing test measurement systems for detector linearity, detector uniformity, and detector spectral responsivity. These systems should be available in 6 months. For a paper outlining NIST's optical power measurement capabilities, contact Fred McGehan, Div. 360, NIST, 325 Broadway, Boulder, Colorado 80303. For more information on calibration services, contact Thomas R. Scott, Div. 724, same address, or phone (303) 497-3651.

## R&D 100 AWARD WINNER

### Image-Preserving Optical Delay

Edward F. Kelley of the Electrosystems Division is the recipient of an R&D 100 Award in 1988 for generating a pioneering photographic "time machine" which, when used with a high-speed camera, permits photographing events which occurred before the camera's shutter is opened.

The system, called an image-preserving optical delay, differs from conventional photography which records an event only when the shutter is open.

This new device, an arrangement of optical components including mirrors and a crystal shutter, allows researchers to take detailed, high-speed photographs of random, that is, nontriggered, events.

It is now used for processes which last from 100 ns to 10 $\mu$s to study materials utilized by the electric power industry.

This system stores optical images of a random event long enough so the shutter of a high-speed camera can be opened and photographs taken of the processes leading to the random event. Kelley has filed a patent application on the system.

Functionally, the optical delay is equivalent to forcing the image to travel an additional 120 m before it gets to the camera. Using a series of concave and planar mirrors, this path length is folded into about 4 m.

The system is rugged enough to be used in a variety of settings. Normal vibration, air currents, and airborne dust have minimal effect on its operation.
[Contact: William E. Anderson, (301) 975-2423]

## RECENTLY ISSUED STANDARD REFERENCE MATERIALS

The Semiconductor Electronics Division announces the release of a new Standard Reference Material (SRM) for **ellipsometrically derived thickness and refractive index of a silicon dioxide film on silicon**. Available for sale to the public through the NIST Office of Standard Reference Materials [for orders, (301) 975-6776], SRM 2530 is separately available for three oxide thicknesses: 50 nm (2530-1), 100 nm (2530-2), and 200 nm (2530-3).

This SRM was developed to respond to industry needs to evaluate the accuracy of ellipsometers, but may also be used as aid in the calibration of various other optical and mechanical thickness monitoring instruments.

Each SRM consists of a 76-mm (3-in.) diameter silicon wafer on which a uniform silicon dioxide layer was grown, patterned, and partially covered with chromium. The certified values were determined from measurements made using the highly accurate ellipsometer developed in the Division and are the ellipsometric parameters delta, $\Delta$, and psi, $\psi$, at a wavelength of $\lambda = 632.8$ nm. The SRMs are also certified for the derived values of thickness and refractive index of its silicon dioxide layer determined by using a two-layer model consisting of a silicon dioxide layer on

Recently Issued SRM (cont'd.)

a thin silicon-rich oxide interlayer. [Contact: Deane Chandler-Horowitz, (301) 975-2084]

**1989 CEEE CALENDAR**

June 27-28, 1989 (Gaithersburg, MD)

**Micropatterning Metrology for the 1990's.** This new workshop is jointly sponsored by the American Society for Testing and Materials Committee F-1 on Electronics, the National Institute for Standards and Technology, and the Semiconductor Equipment and Materials International Micropatterning Division to concentrate on problems in semiconductor manufacturing and quality control associated with critical dimension measurements. Optical, electron beam, and electrical methods now in use as well as proposed future (emerging) methods are considered, and each of these categories is the subject of an individual discussion group. Stress is given to basic metrology underlying practical measurements, test patterns or standards used to verify instrument precision and accuracy, and associated test methods and specifications. The organizers expect workshop attendees to contribute to the goals of (1) identifying current problems and (2) developing recommendations on priorities for the sponsoring organizations in their pursuit of new metrology and standards to help industry address these problems. Tours of CEEE's Semiconductor Electronics Division and of the Center for Manufacturing Engineering's Microelectronics Dimensional Metrology Group are planned.
[Contact: Robert D. Larrabee, (301) 975-2298]

September 11-13, 1989 (Garmisch-Partenkirchen, FDR)

**VLSI and GaAs Chip Packaging Workshop.** The IEEE CHMT Society and the National Institute of Standards and Technology are co-sponsoring the Eighth VLSI Packaging Workshop. Topics to be discussed include VLSI package design; integrated package design; multichip module design; WSI packaging; package thermal design; package electrical design; GaAs IC packaging; VLSI package interconnection options; VLSI package materials and die-attach solutions; and failure mechanism and quality of VLSI packages. All attendees are expected to be specialists working in the field and to participate in discussions.
[Contact: George G. Harman, (301) 975-2097]

December 10-11, 1989 (Gaithersburg, MD)

**Power Semiconductor Devices Workshop**, This Workshop, sponsored jointly by IEEE and NIST, is intended to bring together for interactive participation those actively working in the field of power semiconductor devices. It will be held in conjunction with the 1989 IEEE International Electron Devices Meeting in Washington, DC. Four specific topic areas have been selected: power and high voltage integrated circuits, discrete devices, device and circuit simulation, and packaging. In addition, a special panel on power electronics education will be held. This year's Workshop will specifically solicit attendance from device and circuit users as well as device researchers. Attendees are expected to be prepared to contribute to the development of responses to specific questions that arise in the context of the particular topic areas; a final schedule should be available at the end of October.
[Contact: David L. Blackburn, (301) 975-2068]

February 6-8, 1990 (Phoenix, AZ)

**IEEE Semiconductor Thermal and Temperature Measurements Symposium.** This sixth annual SEMI-THERM symposium is sponsored by the Components, Hybrids, and Manufacturing Technology Society of IEEE in cooperation with NIST and constitutes an international forum for the presentation of new developments

CEEE Calendar (cont'd.)

relating to generation and removal of heat within semiconductor devices, measurement of device temperatures, and the simulation of device and system thermal behavior. Major SEMI-THERM topic areas include thermal measurements; thermal characterization; applications; and simulation, computation, and software.

The program includes keynote speakers, technical presentations, tutorial sessions, workshops, and an exhibit. In addition, the Semiconductor Equipment and Materials Institute (SEMI) and the Joint Electron Devices Engineering Council (JEDEC) have scheduled in conjunction with SEMI-THERM several Standards Committee Task Force meetings, to which attendees are invited.
[Contact: David L. Blackburn, (301) 975-2068]

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☐ Document describes a computer program; SF-185, FIPS Software Summary, is attached.

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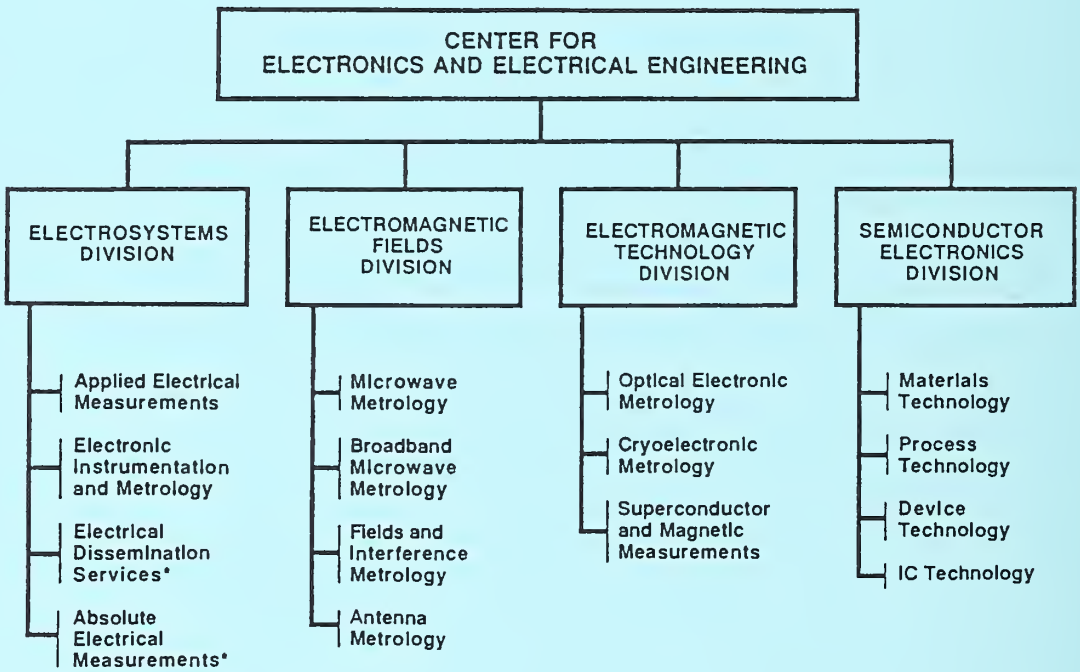


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